Reproductive Phenology of White Box (*Eucalyptus albens* Benth.) in the Southern Portion of its Range: 1997 to 2007

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The abundance of reproductive structures (buds, flowers and capsules) in individual *Eucalyptus albens* trees at four sites was monitored for up to 11 years. Average abundance values for a stand of trees often masked individual differences, e.g. abundant budding (a surrogate for flowering) in consecutive years was never recorded in a stand but it was common in individuals. On average, floral buds appeared in November and flowers were produced between March and November the following year but some trees produced buds as early as March, and in others flowering extended to January. Though summer-flowering was uncommon in this study, some observations from the 1970-80s reported a flowering period of, for example, January to June, suggesting that flowering is now later. Except for peak flowering years, e.g. at three sites in 2006, when virtually all trees flowered, flowering was individualistic suggesting that previous rainfall was not the sole driver. Correlations between bud abundance and previous rainfall suggested that individual trees, or groups of trees, responded to different rainfall events. For example, budding in some trees at all sites (particularly those in the two northern-most sites) was positively correlated with winter rainfall three years previously whereas at the most southerly site, budding in many of the trees was correlated with autumn rainfall four years previously. Such variability may be genetically determined and have positive benefits for seedling recruitment in a variable climate such as Australia's.

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"*All around Sydney, and particularly in our bushland suburbs, the Angophora costata (Sydney Red Gum) are in exceptionally heavy flower. So heavy that the white honey scented blossoms weigh the branches down to give the trees an uncharacteristic domed shape. Why are they busily preparing for such a profusion of seeds to drop this year? What do they know that we don't?*"
Letter to the editor, *Sydney Morning Herald*, 27 November 2006

INTRODUCTION

Woodlands dominated or co-dominated by white box (*Eucalyptus albens*) once extended almost continuously from southern Queensland, along the inland slopes of New South Wales (NSW) into north central Victoria with outliers in the Snowy River area, western Victoria and the Southern Flinders Ranges of South Australia. The woodlands occur on several soil types that, at least for those with a grassy understorey, are relatively fertile and are now used for wheat-growing (Beadle 1981). Consequently the woodlands now occupy a lesser area than they once did. Nevertheless *E. albens* trees are still relatively common across their range and contribute to the aesthetics of the roadsides and farmlands where they occur. However, intact grassy woodlands, i.e. those with relatively undisturbed overstorey and groundstorey, are rare and poorly conserved in the formal reserve system (Prober 1996). They are listed nationally as an endangered ecological community under the *Environment Protection and Biodiversity Conservation Act 1999*.

Natural recruitment of seedlings of *E. albens* is uncommon, at least in the southern part of its range, and has been attributed (Semple and Koen 1997, 2003) to the seedling's inability to compete with exotic species that are now dominant in many groundstoreys of these woodlands. Exotic dominance is probably due to enhanced soil fertility, particularly nitrogen (Prober et al. 2002) and/or phosphorus (Allcock 2002). Other potential limitations to successful seedling recruitment include: reduced seed quantity and quality produced by isolated trees in cleared environments (Burrows 1995), the unlikely coincidence of suitable rainfall for both germination and survival, browsing of seedlings by wingless grasshoppers and domestic and feral animals, minimal seed reserves in the soil due to predation by ants and ready germination of non-dormant seed following rainfall events. A consequence of the last-mentioned is a reliance on an aerial seedbank from which seed is shed intermittently (Semple et al. 2007).

The amount and occurrence of seed fall is primarily determined by a range of prior factors that affect the production of buds and in turn, flowers and fruits. In the case of eucalypts, the inflorescence commences as a bud that differentiates into a cluster of 'bud initials' ('inflorescence buds') that are enclosed by a cap of fused bracts. After the cap is torn and shed, buds develop through 'pin', 'cylindrical' and 'plump' stages until anthesis (Boland et al. 1980). Each bud consists of a basal hypanthium, in which the ovary is wholly or partially embedded, and the calyptera (operculum), which encloses the stamens. In species of the *Symphomyrtus* sub-genus, the operculum is double-layered and the outer calyptra is shed early or, as in the case of *E. albens*, fuses with the inner, which is shed at anthesis (Hill 1991). Following pollination (by insects, birds, small mammals) and fertilization of ovules, seed and fruit development commences. Fruits (capsules) expand, change colour from 'green' to 'brown' and become increasingly woody. Dehiscence is initiated by twig death or the formation of an abscission layer that cuts off the sap flow to the capsules. Fertilised ovules are shed as seed and unfertilised ones (the majority) and ovulodes as 'chaff'.

In an earlier study of *E. albens* trees near Cowra, NSW, Semple et al. (2007) reported that seed fall was highly variable between trees as was the occurrence and abundance of flowers. Moderately abundant flowering occurred every second year on average and appeared, at least in the period 1996 to 1999, to be associated with above-average rainfall in winter and spring the previous year. Whether biennial flowering was usual or whether it was associated solely with previous above-average rainfall could not be determined from data that was limited to scattered paddock trees at one site and only four years of observations.

The study reported below formed a component of a broader study investigating the role of various factors (seedbed, rainfall, seed fall, etc.) in the seedling recruitment of woodland eucalypts. It aimed to (a) document the seasonality, frequency and abundance of floral buds, flowers and capsules in individual trees within stands that were distributed across the southern range of *E. albens*; and (b) examine the relationship between rainfall and the production of floral buds over a longer period than was the case at Cowra.

METHODS

Site selection

The basic requirements were for stands containing at least 12 trees of variable size, as indicated by diameter at breast height (DBH), that were readily (and safely) accessible. The latter was satisfied by occurrences beside roads that were travelled regularly in the course of normal business or recreation. Small trees that were unlikely to flower were ignored but these were only evident at one site (Molong). An additional requirement was that stands were distributed relatively evenly across the southern distribution of the species, viz. from central western NSW to north-eastern Victoria. There were no requirements with respect to aspect, altitude or condition of the stand though those with unhealthy, e.g. dieback-affected, trees were avoided. Four sites, located to the north and south of the earlier study site near Cowra, were selected (Fig. 1). All stands were parts of 'corridor communities' (e.g. Fig. 2) except at Molong where the stand extended into the adjacent paddock. None was located near a supplementary source of water, such as a dam or watercourse, and spatially variable run-on (with associated nutrients) from the roadside or adjacent land appeared unlikely. An unintended consequence of the selection procedure was that as latitude increased, altitude and mean annual rainfall generally decreased (Table 1).

Monitoring

Trees were observed with binoculars by the same observer [WS] at regular intervals – ideally monthly during bud formation and flowering (usually mid/late autumn to late spring, when new floral buds also become evident). At each observation the abundance

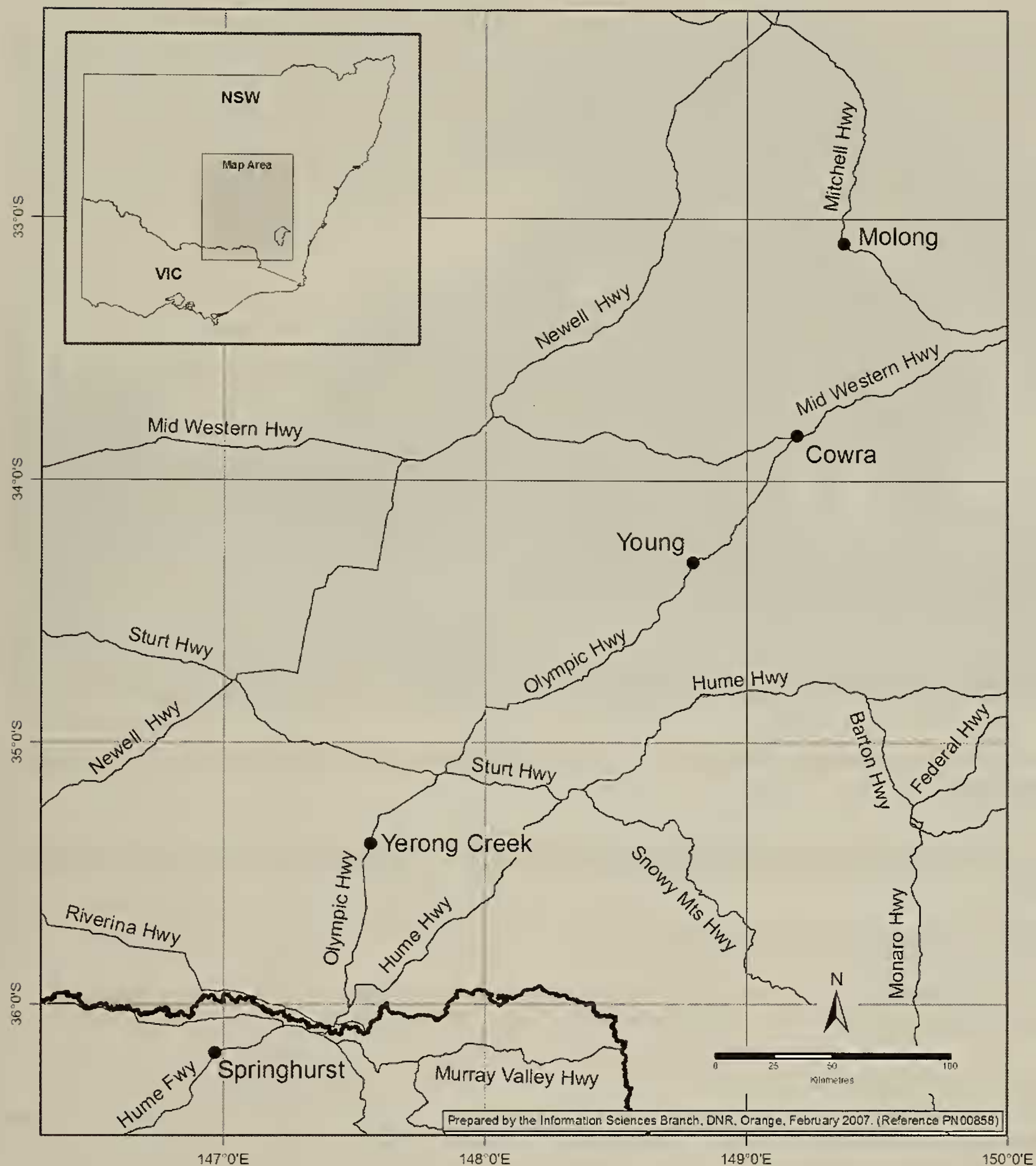

Figure 1. Location of towns nearest the four *E. albens* sites in the present study and an earlier one near Cowra.

of reproductive structures across the canopy of each tree was assessed on a 6-point integer scale: 0 (none), 1 (one to very few), 2 (scattered or a few small clumps), 3 (obvious and dispersed across most of the canopy), 4 (very abundant), 5 (maximum possible). Structures assessed were: pin buds, buds ('cylindrical' and 'plump' stages were not distinguished), flowers (up to withering of anthers) and capsules (= all post-flowering structures with no distinction made between fruits at different stages of maturity). Initial attempts at assessing 'inflorescence buds' were abandoned as they could not be distinguished reliably from the vegetative buds that were produced each autumn and spring with the latter period often coinciding with the presence of inflorescence buds. Observations were less frequent over summer and also during periods when bud production was nil or minimal (and hence, flowering was unlikely to occur). Inevitably over a monitoring period of up to 10 years, there were periods when bud and/or flower activity were missed.

Figure 2. A typical roadside stand of *E. albens.* The monitored stand at Yerong Creek in November 2006 [photo 245/6].

Table 1. Brief details on the monitored roadside stands of *Eucalyptus albens* listed in order from north to south.

Stand name	Locality and latitude	Tree nos. at start (end [A])	DBH [B] (m): mean and range	Altitude (m a.s.l.)	Mean annual rainfall (mm)	Period of regular monitoring [C]
Molong	6 km SW of Molong 33° 7′ 12″ S	13 (12)	0.62 (0.11–1.53)	600	700	Mar. 2000 – Nov. 2006
Young	Rest area, 7.2 km N of Young 34° 17′ 12″ S	12 (11)	0.67 (0.41–1.15)	550	650	July 1997 – Nov. 2006
Yerong Creek	3.6 km S of Yerong Creek 35° 25′ 00″ S	19 (18)	0.52 (0.14– 0.99)	230	530	Jan. 1997 – Nov. 2006
Springhurst	Rest area, 6 km S of Springhurst 36° 14′ 30″ S	19 (18)	0.54 (0.18– 2.08)	180	610	Dec. 1996 – Nov. 2006

A Tree decline was due to deliberate removal associated with roadworks (Molong and Springhurst), ringbarking (Young shortly after observations commenced) and tree fall (Yerong Creek).
B Diameters of any multi-trunked trees have been summed.
C All stands were revisited in early 2007 to assess the size of the 2007 bud crop though Molong observations were ignored because of the confounding effects of a wildfire in November 2006.

Regular monitoring ceased in November 2006 though the bud crop for 2007 was assessed on number of occasions at all sites except at Molong where most of the trees were severely burnt in November 2006 [though monitoring at this site was maintained so as to document the effects of fire on the trees and the groundstorey (see Semple and Koen 2008)].

Data analysis and presentation

Data for all types of floral bud have been amalgamated for presentation purposes. Where trees were not observed as frequently as desired (i.e. missing monthly observations), the abundance of reproductive structures has been interpolated when little change was known to have occurred. However, where new structures appeared between these extended observation periods, the periods of unobserved activity have been shown as 'missing data' on graphs of abundance of structures.

Averaging the abundance ratings of flowers across all trees at a site at each time of observation was misleading because individual trees flowered over varying periods of time (or failed to flower at all) and times of maximum flower abundance in individual trees did not always coincide. Hence, average values across the flowering season implied lower abundance than was the case. Conversely, floral buds usually developed synchronously in trees; and averages of maximum values prior to flowering provided an indicator of potential flowering in a stand in any one season. Bud abundance has generally been used as a surrogate for overall flower abundance in the analyses presented here.

The suggestion that larger/older eucalypts flower more frequently and heavily than smaller ones (various authors cited by House 1997) was examined via correlations between DBH and the frequency of abundant budding (abundance rating ≥ 3) of trees at each site. Two sets of DBH values were used – averaged and summed DBHs for multi-trunked trees.

Associations between rainfall and bud abundance were examined for each site and for each tree. The interpolated monthly rainfall (Jeffrey et al. 2001) at each site was summed in various periods: calendar year, warm (September to February of following year) and cool (March to August) season, and actual season (autumn, winter, etc) for each year of data, 1986 to 2006. Linear correlations were calculated between each of these rainfall periods and the maximum bud abundance (usually in summer each year) for (a) each site (mean values), and (b) for each tree.

RESULTS

Abundance of buds and flowers in stands

Average abundance ratings for floral buds and flowers over time at the four sites are presented in Fig. 3. Low abundance ratings (<3) generally indicated very low numbers of structures and can largely be ignored – apart from cases of flowering at low levels over an extended period. The occurrence of abundant budding (mean rating of ≥ 3) was uncommon at most sites: three in seven years at Molong, three in nine years (ignoring incomplete data for 1997) at Young, two in 10 years at Yerong Creek and Springhurst. Between these abundant budding years, at least some of the trees produced buds and flowers, sometimes at very low levels, except at Springhurst in 1997, 1998, 2000 and 2001 when no buds or flowers were observed (though very low level budding and flowering may have been missed).

Periods of abundant budding tended to occur every second or third year but were less frequent at Springhurst. Some stands budded abundantly in the same years (e.g. 2001 and 2006) but the sequence of budding in the two southerly stands, particularly at Springhurst, was usually different from those in the north. Years of high average bud abundance were followed by at least one year of low abundance. Abundant budding levels in each stand were positively associated with the proportion of trees producing abundant buds in that year (compare Figs. 3 and 4).

Times of bud formation and flowering in stands

Pin buds were usually evident between October and December. Buds were at a maximum by early summer and abundance ratings rarely declined prior to the commencement of flowering.

During peak flowering periods when most trees flowered abundantly, flowering in some trees was usually evident in March (though as early as February in some trees at Young in 2003; Fig. 5a) with the latest commencing in June or July. Flowering was usually complete in all trees by October or November. Some trees flowered for a long period between March and November but most trees flowered for only a few months. In non-peak flowering years when only some trees flowered, some trees, usually those with very few buds, did not commence flowering until August or September.

Some of the Molong trees did not follow these trends. For example, the main flowering period for tree M194 in 2003 was from November to January 2004. Some trees produced pin buds very early in the season: two trees (M181 and M192) during March/August 2000 and one tree (M181 again) in May 2002;

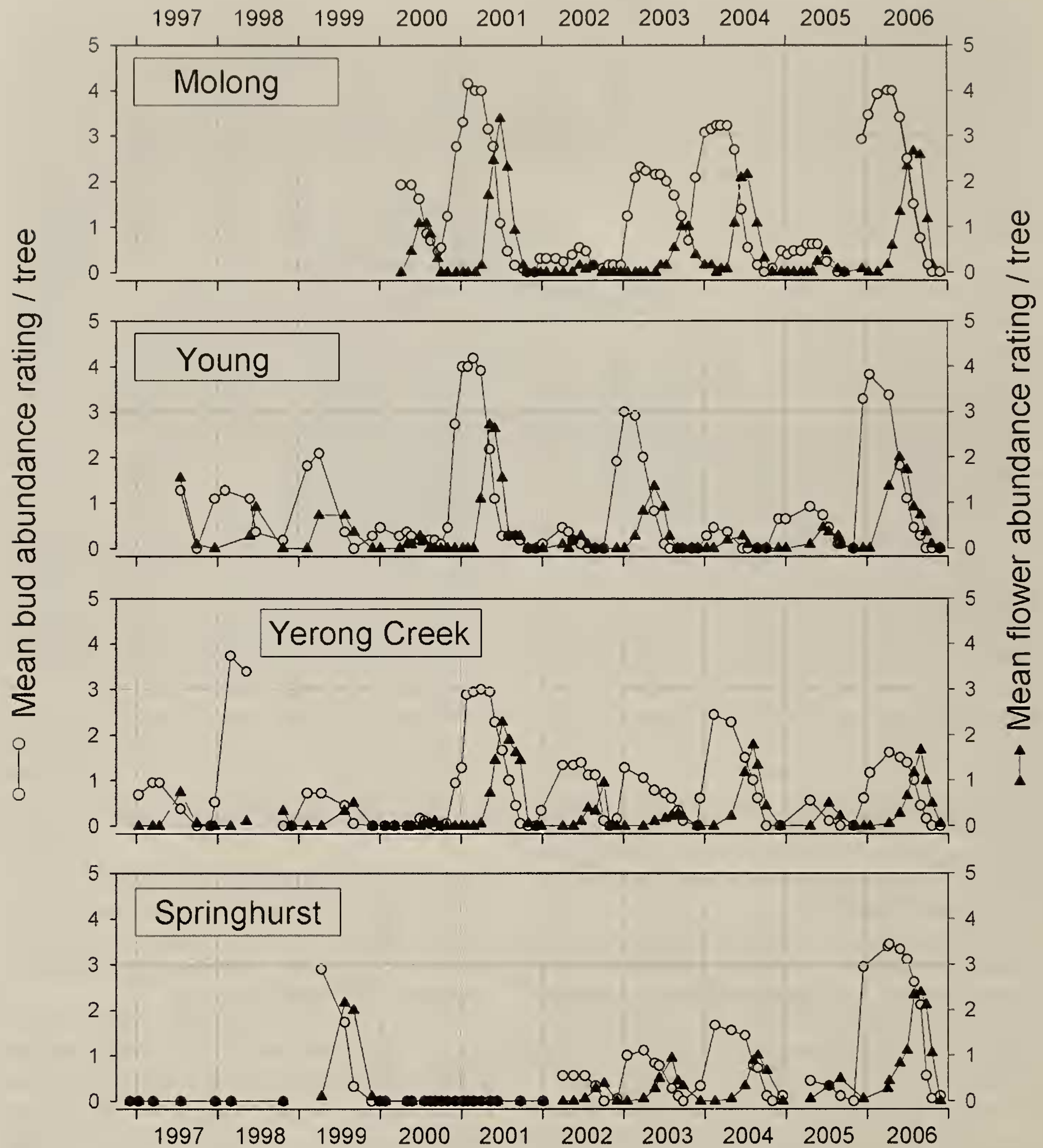

Figure 3. Mean abundance ratings (0-5) for floral buds (o) and flowers (▲) over varying periods of times at four stands of *E. albens*. Sites are presented in order from north to south. Periods of missing data have generally been smoothed over except when bud initiation, or a major flowering event (i.e. Yerong Creek in 1998), were missed.

but these buds matured slowly and were eventually indistinguishable from buds produced at the normal time (~November). Small quantities of early pin buds were also produced by a few other trees at Molong, and one at Young, but they apparently failed to develop. Unusually, a small number of buds that became evident in October/November at Molong produced flowers in November/January. This occurred at trees M177, M192 and M181 in 2003, 2004 and 2005 respectively (Fig. 5b)

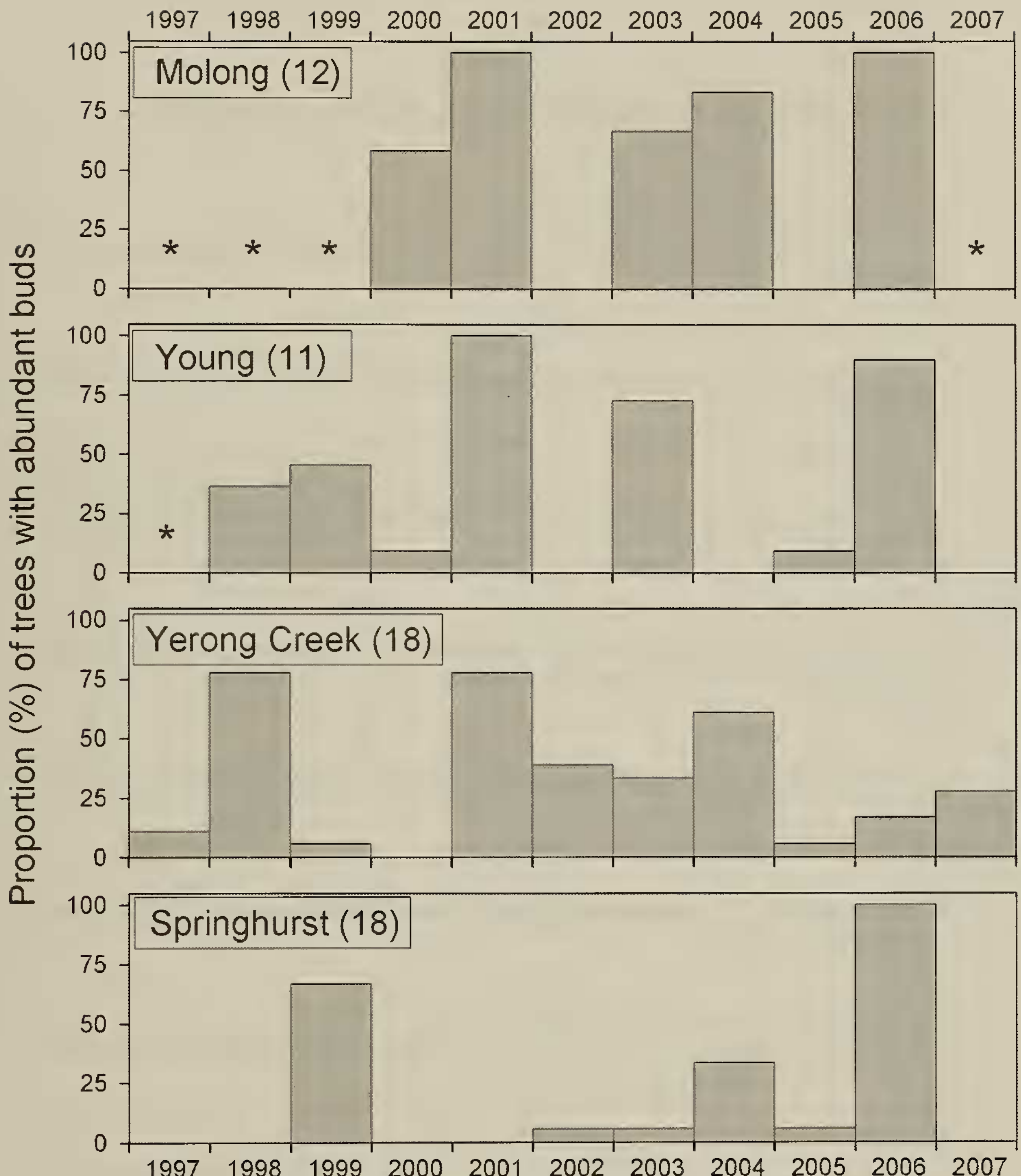

Figure 4. Proportion (%) of trees in each stand that produced abundant (rating ≥ 3) floral buds in any one year. * = nil or incomplete data. Numbers of trees monitored for the full period at each site are shown in parentheses. Bud abundance in 2007 was determined from a few strategically-timed observations.

Budding and flowering of individual trees within stands

Frequency, abundance and duration of flowering varied between trees at all sites, particularly in years when flowers were not abundant. Space prohibits the presentation of all data. Young and Molong are presented as examples in Figs. 5a and 5b. During the 'big' budding/flowering years at Molong (2001, 2004, 2006 and to a lesser extent 2003), Young (2001, 2003 and 2006), Yerong Creek (1998 – presumably as the main flowering period was missed, 2001 and to a lesser extent 2004) and Springhurst (1999 and 2006), all trees flowered – except for one or two trees at Springhurst in 1999 and Yerong Creek in 2004 – though with varying levels of intensity.

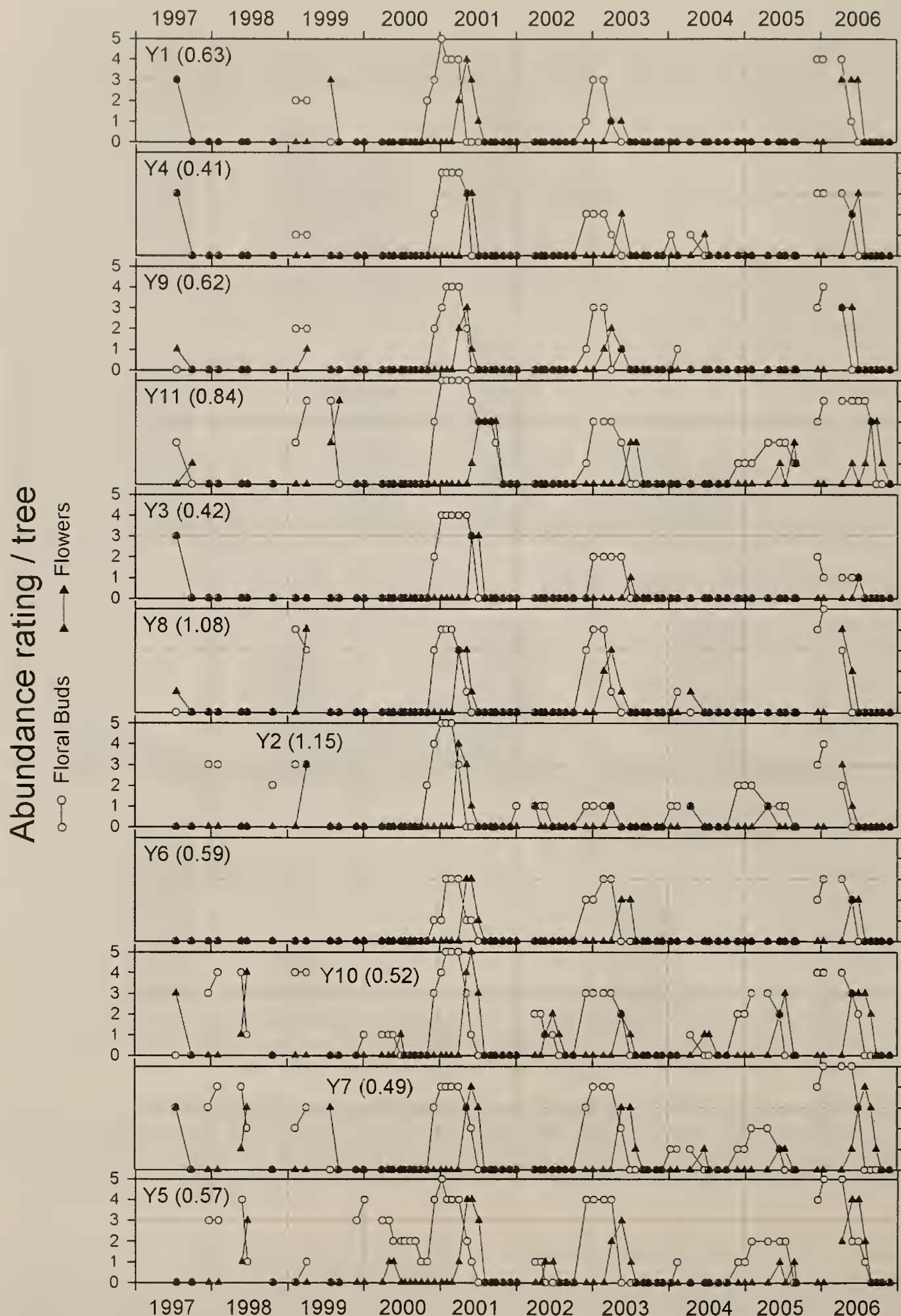

Figure 5a. Floral bud (o) and flower (▲) abundance ratings (0-5) for eleven *E. albens* trees on a roadside near Young: July 1997 to November 2006. Tree identification numbers are preceded by the letter Y, and have DBH (m) in parentheses.

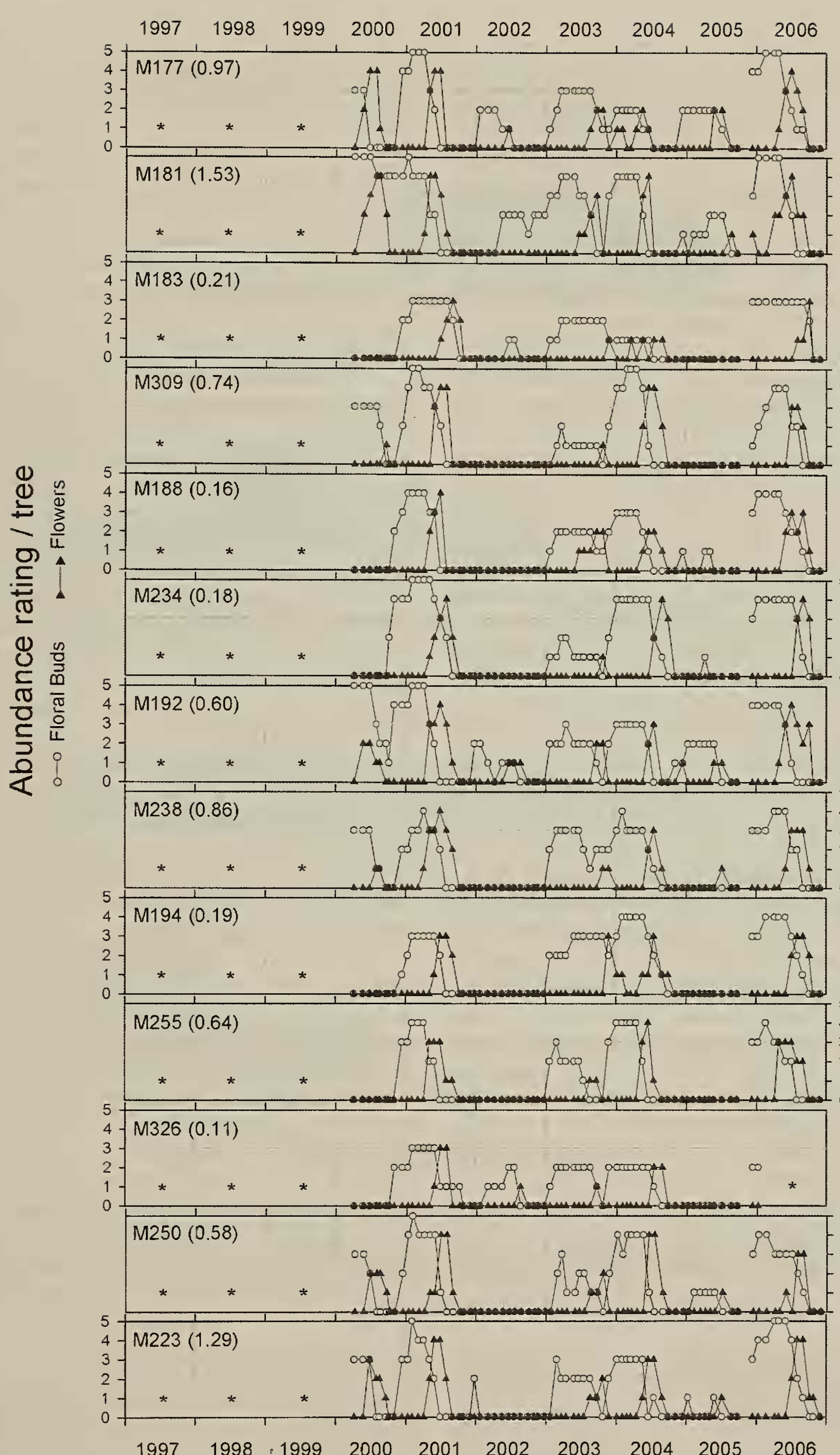

Figure 5b. Floral bud (o) and flower (▲) abundance ratings (0-5) for thirteen *E. albens* trees on a roadside near Molong: March 2000 to November 2006. Tree identification numbers are preceded by the letter M, and have DBH (m) in parentheses. * = no data.

Abundant budding (mean rating ≥3) in consecutive years across a stand was rare (Fig. 3) but it was often recorded in individual trees. At Young, three trees (Y2, Y5, Y7) budded abundantly in consecutive years on one occasion, and another (Y10) on two occasions (Fig. 5a). Abundant budding in consecutive years was less frequent in trees at Springhurst (two trees on one occasion each) but considerably higher at Yerong Creek: eight trees on one occasion and four trees on two occasions but in the case of two of the latter trees, the second occasion extended over four years, 2001 to 2004. Despite the shorter period of observation at Molong, four trees (M177, M309, M194, M255) produced abundant buds in consecutive years on one occasion and five trees (M181, M192, M238, M250, M223) on two occasions – though in some cases buds declined prior to flowering, e.g. at M255 in 2003 (Fig. 5b).

Some trees budded abundantly more often than other trees at all sites (Fig. 6). This was particularly evident at Molong where five (41%) trees budded abundantly in five of the seven years observed. At the other extreme, six trees at Springhurst produced abundant buds in only one of the 11 years observed. Larger trees tended to produce abundant buds more frequently than smaller ones, at least for the range of DBHs shown in Table 1, but the overall association was low, ranging from $r = 0.23$ at Young to $r = 0.70$ at Molong.

Production and decline of capsules

The abundance of capsules in individual trees over time reflected the varying flowering patterns, and minor flowering events (bud abundance ≤2) generally had an imperceptible effect on the crop of capsules.

Though peak flowering events (Fig. 3) were important in replenishing the capsule crop in stands (Fig. 7), even minor flowering events (mean bud abundance ≤2) played a role because some trees flowered abundantly during these periods. Though the crop consisted mainly of immature capsules following each peak flowering, for much of the time crops of different ages were present in the canopies – except at Springhurst where flowering was infrequent. For most of the time at this site, average capsule abundance was low (≤2) and any fruits present were likely to have been over-mature, i.e. dehisced.

Relationship between the occurrence of budding and preceding rainfall

Linear correlations were examined primarily for significant correlations between bud abundance and recent (≤ 5 years previously) rainfall that the site (i.e. mean values) shared with many of the individual trees. A subset of the rainfall data, cool-season and warm-season, is presented in Fig. 8.

Mean maximum bud abundance at Molong was significantly correlated ($r = 0.81$) with winter rainfall three years previously (Fig. 9a) and warm-season rainfall five years previously ($r = 0.82$); and negatively correlated with cool-season ($r = -0.76$) and/or winter ($r = -0.78$, Fig. 9b) rainfall four years previously. Only three trees exhibited all correlations but most showed one or two. Bud abundance at four trees (M181, M192, M238, M250) was not significantly correlated with recent rainfall.

At Young, mean maximum bud abundance was also significantly correlated ($r = 0.69$) with winter rainfall three years previously (Fig. 9c) and negatively with winter rainfall four years previously ($r = -0.64$, Fig. 9d) but also with summer rainfall one year previously ($r = 0.72$). None of the individual trees showed all three correlations. Bud abundance for the first five trees in Fig. 5a was correlated with winter rainfall three years previously and summer rainfall one year previously. Figure 5's last three trees, which tended to produce abundant buds in most years, were not consistently associated with these lagged rainfall series but bud abundance at two of them (and also Y2) was significantly negatively correlated with winter rainfall four years previously.

Mean maximum bud abundance at Yerong Creek was significantly correlated with spring ($r = 0.62$) and/or warm season ($r = 0.64$) rainfall three years previously. Budding at seven of the 18 trees with a complete set of data showed a similar pattern. Unlike Molong and Young, the positive correlation with winter rainfall three years previously and the negative correlation with winter rainfall four years previously were evident at only one or other of four trees, and across all trees these correlations were weak (Figs. 9e and 9f).

At Springhurst, mean bud abundance was significantly negatively correlated with rainfall two years previously: calendar year ($r = -0.72$) and cool-season ($r = -0.66$). One or both of these correlations were evident for 13 of the 18 trees with a complete data set but budding at nine trees was also significantly positively correlated (r values ranging from 0.60 to 0.74) with autumn rainfall four years previously. Correlations with winter rainfall three and four years previously were weak (Figs. 9g and 9h).

Across all 59 trees, bud abundance at 24 was significantly positively correlated with winter rainfall three years previously. Such trees were present at all sites, particularly at Molong and Young. At Yerong Creek, seven trees were correlated with rainfall three years previously: one with winter rainfall,

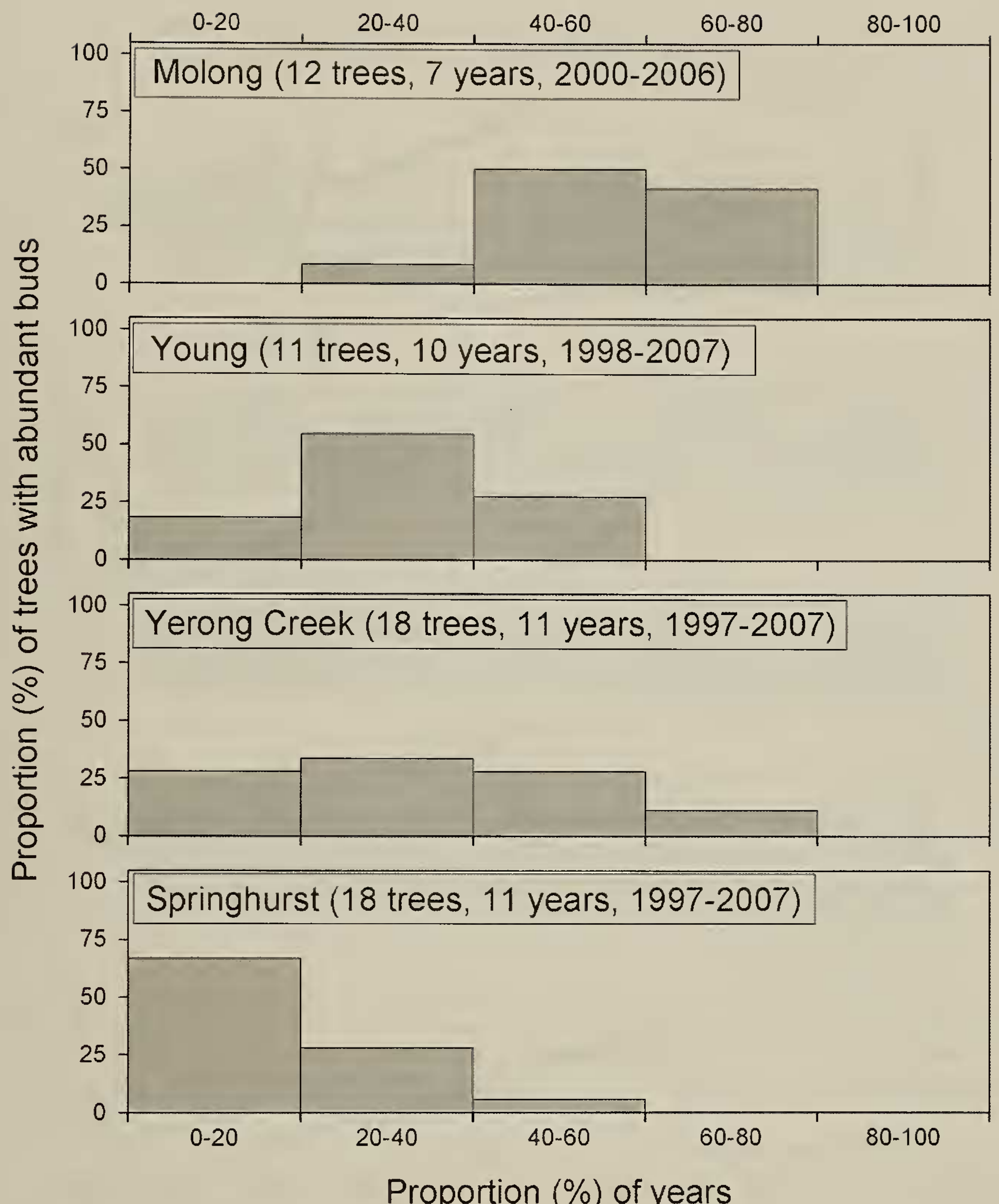

Figure 6. Proportion (%) of trees in each *E. albens* stand that produced abundant floral buds (rating ≥ 3) grouped by the proportion of years of observation (years with incomplete data excluded). For example, 12 trees (67% of 18 trees) at Springhurst were observed to produce abundant buds on just two or fewer occasions (18% of 11 years). Except for Molong, bud assessments for 2007 are included.

three with winter and spring rainfalls and three with spring rainfall. (Budding at a few other trees was also correlated with warm-season rainfall but it was most apparent at Young where six of the 11 trees were positively correlated with summer rainfall one year previously.) Only a few trees were correlated with rainfalls two and four years previously and for most it was negative. Contrary to all the other sites, nine of the 18 trees at Springhurst were positively correlated with autumn rainfall four years previously. Budding in most (but not all) trees therefore seemed to be dependent on cool-season (either winter or autumn) rainfall three or four years previously.

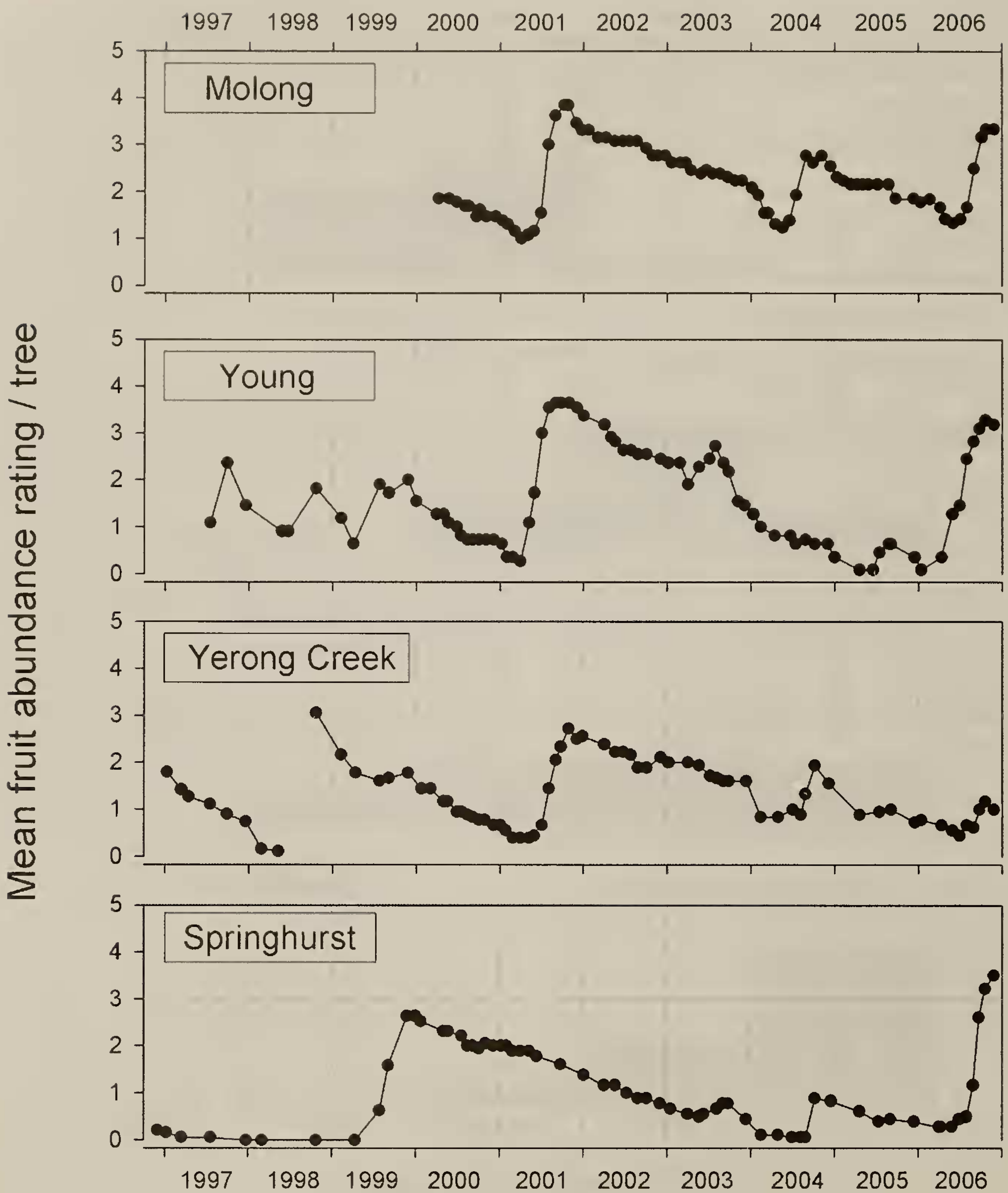

Figure 7. Mean abundance ratings (0-5) for capsules over time at four stands of *E. albens*. No distinction is made between immature (usually the main component on peaks and steeply rising limbs on the graphs) and over-mature capsules (usually the main component towards the ends of falling limbs on each graph).

DISCUSSION

Budding and flowering times

Floral (pin) buds were usually first evident around November – apart from some unusual occurrences of early budding at a few trees at Molong (and again in March 2007 and 2008; Semple and Koen 2008). Buds were at a maximum by early summer and bud abundance ratings rarely declined prior to the commencement of flowering. Even so, bud shedding

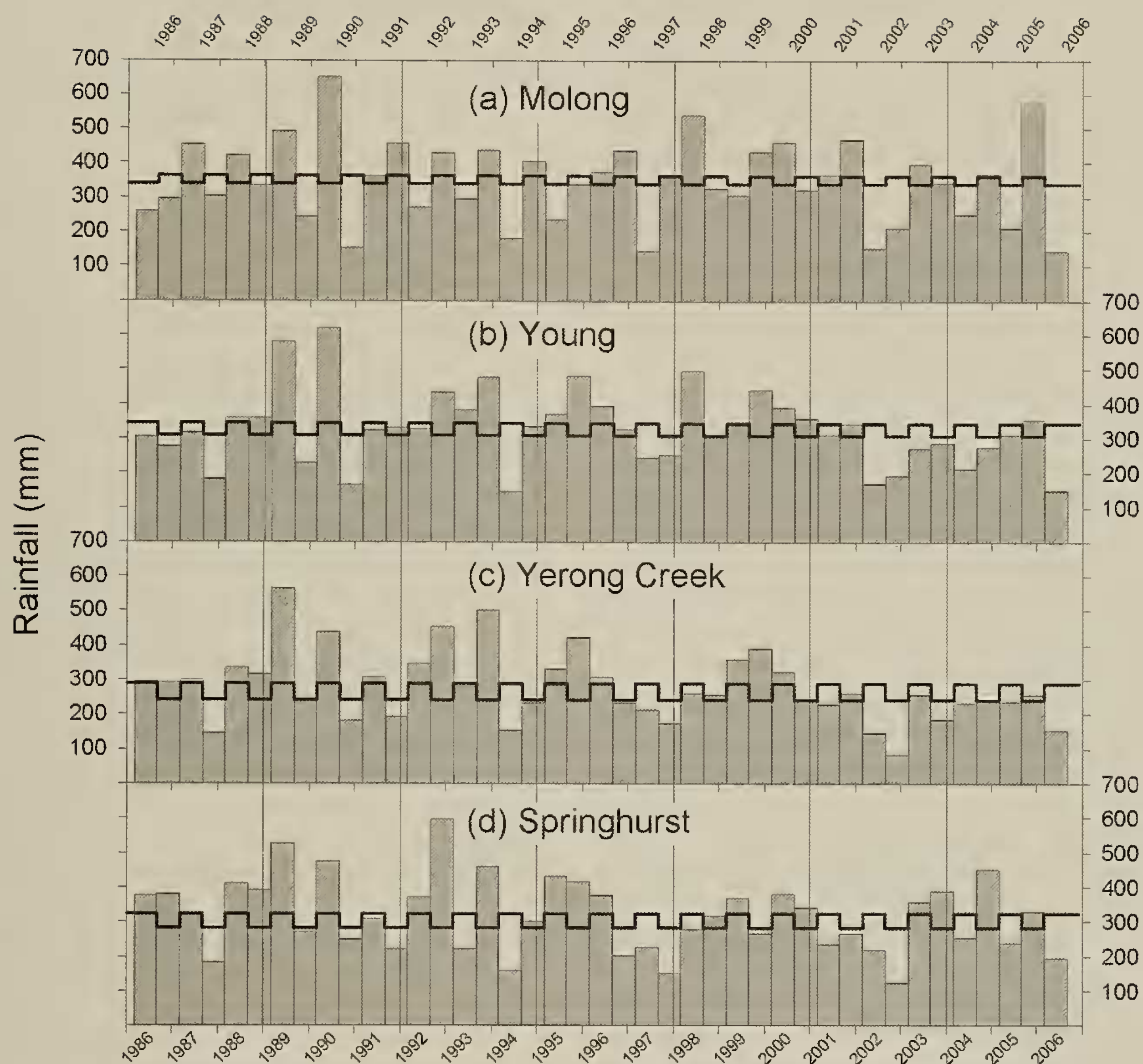

Figure 8. Cool (March to August) and warm (September to February of the following year) season rainfall from stations near the four *E. albens* monitoring sites. Seasonal data derived from monthly interpolations (as per Jeffrey et al. 2001) and long term means (thickened lines) from incomplete Bureau of Meteorology data: Molong (1884-2006), Young (1871-1991), Yerong Creek (1885-2007), Springhurst (1900-2007).

was probably common as has been reported for eucalypts (Florence 1996) and for *E. albens* at Cowra (Semple et al. 2007) but was not usually detected by the relatively coarse abundance rating scale used in this study. Flowering generally occurred from March to November in the year following budding.

The first occurrence of buds and the flowering period were consistent with previous observations by Clemson (1985) and Semple et al. (2007) but the flowering period was inconsistent with observations by others, e.g. mid/late summer to winter, or autumn to winter (see Table 2). Summer flowering is possible as was demonstrated by a few trees at Molong (though few flowers were produced and flowering did not extend beyond January) and for two trees at Young in 2003 (when their main flowering period commenced in February). As some of the reports of an earlier flowering period, i.e. between summer and winter, predate the early 1990s, is it possible that the flowering period has changed since *c.*1990 – perhaps in response to increased frequencies of years of below-average rainfall (e.g. Fig. 8) or even higher temperatures in recent times. Without access to the original observations, it is difficult to establish but the possibility of a later and longer flowering period in recent times cannot be ruled out.

Leigh's (1972) report of a longer flowering period in NSW compared to southern Queensland

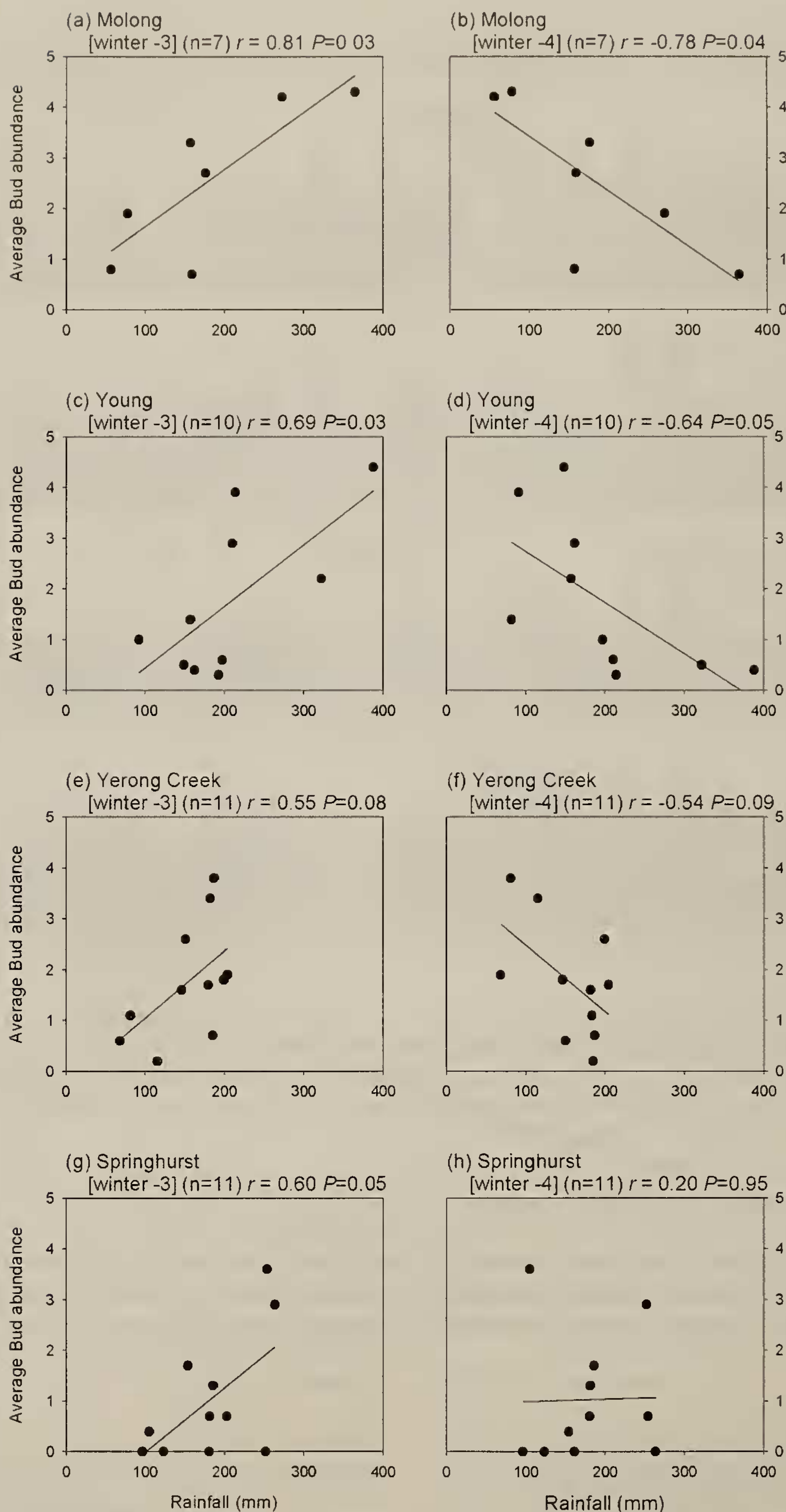

Figure 9. Correlations between maximum mean annual bud abundance and winter (June-August) rainfall 3 and 4 years previously at four *E. albens* monitoring sites. Number of years of data indicated by 'n'.

suggested that it may be longer in the south, e.g. at Springhurst, but this was not evident in the data, albeit limited by only two peak flowering periods in that stand. Nor was it evident in Stelling's (1998a, b) report for southern NSW (Table 2).

Temporal and spatial variation in flowering

Variable flowering periods and intensities between individual eucalypts in a stand in any one year is well known and has been attributed variously to tree age/size, health and probably genotype as well as local variations in elevation, soil types and moisture availability (House 1997, Wilson and Bennett 1999). As indicated by the ranges of DBHs (Table 1), trees of variable size and presumably age were present in each stand but the association between DBH and the frequency of abundant budding was generally weak. Elevation, soil type and moisture availability appeared to be relatively uniform in each stand, except for the hilltop stand at Young where elevation varied by ~2 m. As budding intensity varied (a) between trees in each stand in the one year and (b) between individuals across years, e.g. some budded abundantly in consecutive years whereas others did not, prior rainfall alone cannot explain flowering in a stand. If it did, then all trees would flower (or produce buds) in a similar manner each year.

Nevertheless prior rainfall is important for tree health and its varying occurrence and abundance would be expected to have varying effects on the production of new leaves and reproductive structures. For example, Porter (1978) in attempting to explain correlations between previous rainfall (and temperature) and honey production (= flowering intensity in a stand) from *E. tricarpa* (with similar phenology to *E. albens*), noted that leaf growth was favoured by wet summers but not by cool wet winters - though stored water from the latter favoured growth of floral buds in the following spring.

The data presented here indicate that individual (and sometimes groups of) trees responded differently to the same rainfall cues – except perhaps in those years when most trees budded abundantly (e.g. Fig. 4). This was supported by the examination of correlations between bud abundance and previous rainfall: bud abundance in some trees was not correlated with prior rainfall (at least in the previous five years) whereas other trees in the same stand were correlated with differing rainfall events. Even so, there were some broad correlations between mean bud abundance in a stand and previous rainfall e.g. between winter rainfall three years previously (positive) and four years previously (negative) in the two northern-most stands but these associations

Table 2. Flowering periods of Eucalyptus albens as reported by various authors.

Flowering period	Area	Source
Late summer and sometimes into winter	SE Australia	Kelly *et al.* 1977
January to June	SE Australia	Costermans 1983
February to July	central western NSW	Schrader 1987
March to May	SE Australia	Brooker and Kleinig 1990; Boland *et al.* 1992; Nicolle *et al.* 1994
April to July (Qld) or August (NSW)	SE Australia	Leigh 1972
May to September	southern NSW	Stelling 1998a, b
Autumn to late spring	near Cowra, NSW	Semple et al. 2007
April to November	SE Australia	Clemson 1985

did not extend to stands further south (Fig. 9) where mean bud abundance was correlated with other previous rainfall occurrences. Varying genotypes within and between stands would seem to be the mostly likely explanation for these results; though phenotypic variation due to (undetected) fine-scale variation in resource availability cannot be ruled out. Nevertheless, the presence of such variation would increase the likelihood of floral bud and hence, seed production in at least a few trees in each stand in most years.

The role of flowering (and seeding) in seedling recruitment of woodland eucalypts

The availability of a seedbank is only one of a number of factors that affect seedling recruitment. The success of seedbed-manipulation experiments over a number of years in the eucalypt woodland belt (e.g. Semple and Koen 1997, Lawrence et al. 1998, Geeves et al. 2008) suggests that sufficient and timely rainfall for germination and seedling establishment is not a rare occurrence. However, unlike parts of Victoria, seedling recruitment of woodland eucalypts is rarely observed in NSW. For the most part, this is probably due to the absence of a seedbed that provides exposed mineral soil and reduced herbaceous competition – a consequence of relatively high fertility soils (Beadle 1981) and groundstoreys that are often dominated by exotic species (Prober 1996) in the box (e.g. *E.albens* and *E. melliodora*) woodlands of central and southern NSW. Though appropriate seedbeds can be deliberately (or accidentally) prepared, e.g. by applying herbicides or cultivating near trees, their 'natural' occurrence is largely dependent on high intensity grazing (e.g. Curtis and Wright 1993), drought (e.g. Curtis 1990) or fire (e.g. Cluff and Semple 1994, Semple and Koen 2001) though in the latter case, exotic species if present, rapidly recolonise negating any initial benefits for the eucalypt seedling. Nevertheless, when rainfall, seedbed and other favourable conditions do coincide, the on-going availability of seed, even if in small amounts in a few trees, is critical for successful recruitment. A case in point is the Molong site that was burnt in late 2006. Though the developing 2006 seed crop was destroyed, a small amount of seed was present from earlier (2004?) flowerings (Fig. 7) and this yielded some seedlings beneath a few trees (Semple and Koen 2008). Despite suboptimal rainfall, most of these seedlings were still alive in early 2009 – probably due to the localised absence of competition from exotic herbage.

Predicting the future?

The view expressed by the letter-writer at the start of this paper implies that flower abundance is an indicator of some future meteorological event. Such views are not uncommon, e.g. as reported by Duff (2007) for observations of box trees near Jeparit in Victoria. Results presented above suggest that bud (or flower) abundance did not provide much information on past, leave alone future rainfall events.

CONCLUSIONS

In general, floral (pin) buds appeared in November and flowers were produced during the following March to November. Flowers were produced by at least a few trees in each stand each year except for the southern-most stand. However, the frequency of abundant budding, when most or all of the adult trees flowered abundantly, declined from about 4.3 years in 10 in the northern-most stand to two years in 10 in the south. For each tree stand, these occurrences were important for maintaining its aerial seedbank. Without replenishment, capsule abundance was low after two to three years.

However, the production of reproductive structures in individual trees was often at variance to the stand 'average'. In terms of the first appearance of floral (pin) buds, it could be as early as March (rather than the November 'average'). Flowering in some trees commenced as early as February (compared to the March 'average') or did not finish until January (compared to the November 'average'). Variations such as these were usually evident in a few trees, particularly those at Molong, suggesting a degree of 'plasticity' in populations at the centre of the north-south distribution of *E. albens*.

Unlike average bud abundance in tree stands, where a high abundance year was always followed by a year of low abundance, some individual trees budded abundantly each year over periods ranging from two to four years. Individual differences such as these suggest – contrary to our suggestion from an earlier but shorter (1995-1999) observation period at Cowra (Semple et al. 2007) – that prior rainfall in a particular season is not a general determinant of bud (flower) abundance, except perhaps in those years when all trees flower abundantly. Such variability may have positive benefits for successful reproduction in a variable climate such as Australia's.

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